IMPACT OF VARIOUS HERBAL EXTRACTS ON TECHNOLOGICAL FUNCTIONALITY OF YOGURT

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Abstract

This study investigated the production and quality assessment of functional yogurt fortified with various herbal aqueous extracts, including: turmeric (*Curcuma longa*), sage (*Salvia officinalis*), majorana (*Origanum majorana*), St. John's Wort (*Hypericum perforatum*), hibiscus (*Hibiscus rosa Sinensis*), indian saffron (*Curcuma longa*), parsley (*Petroselinum crispum*), stevia (*Stevia*), silymarin (*Silybum marianum*) and dill (*Anethum graveolens*). The primary objective was to evaluate the impact of these botanical additives at different concentrations (1% and 3% w/w) on the physicochemical properties and sensory profiles of yogurt manufactured from industrial skim milk (8.8% total solids, 0.2% fat, 3.2% protein). Physicochemical analysis revealed that the pH of the fortified samples generally ranged between 3.46 and 3.77, with an outlier in sample 16 reaching 4.54. Titratable acidity varied significantly from 0.28% to 0.73%, while fat content ranged from 0.20% to 1.60%. Organoleptic evaluation assessed aroma, syneresis (whey separation), color, cut clarity, and firmness. Sample 18, fortified with 3% John's Wort, emerged as the best-performing formulation, receiving the highest evaluations for aroma ("Very liked"), cut clarity, and firmness ("Very firm"), while showing no syneresis. Samples 5 (1% John's Wort) and 4 (1% Turmeric) also demonstrated strong consumer acceptance and desirable structural stability. In contrast, sample 17 (2% Silymarin) and the non-fortified control sample (sample 0) showed weaker performance, frequently associated with less appealing aromas and pronounced whey separation. Overall, the results indicate that herbal fortification—especially with John's Wort—can markedly enhance both the sensory qualities and physical stability of skim milk yogurt, supporting its potential use in the development of innovative value-added dairy products.

Keywords: Yogurt, functional food, herbal extracts, fortification, sensory evaluation, structural stability

Introduction

Yogurt is defined as a fermented dairy product produced through the symbiotic action of Lactic Acid Bacteria (LAB), specifically *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus*. These microorganisms convert lactose into lactic acid, which lowers the pH of milk and causes the aggregation of casein proteins into a complex three-dimensional gel network. This process is essential for creating the unique texture, aroma, and cooling taste that make yogurt a globally popular "superfood" associated with health benefits such as improved digestion and the prevention of cardiovascular diseases (FAO, http://www.faoorg/economic/est/estcommodities/dairy/en). In recent years, consumer interest in low-fat and fat-free dairy products has grown considerably, largely driven by increasing awareness of health issues such as obesity and diabetes. Nevertheless, reducing or removing milk fat can negatively affect product quality, resulting in defects such as decreased viscosity, poor texture, and increased syneresis (whey separation). To address these limitations, the dairy industry has adopted several approaches, including fortification with milk solids, the use of advanced processing methods such as high-pressure homogenization, and the incorporation of functional ingredients (Dabia et al., 2018; Hashim et al., 2021; Hyseni et al., 2022). Previous investigations in Macedonia emphasize the transition of yogurt from a traditional staple to a scientifically standardized functional food. Their studies primarily focus on functional fortification, microbiological safety during storage, raw milk quality, and the impact of processing on the final product's characteristics. Hyseni et al. (2024) investigated the bioconversion of a milk-liquid whey mixture into yogurt supplemented with Aronia (*Aronia*

melanocarpa). Texturally, these functional yogurts showed higher levels of cohesiveness and springiness but lower hardness and adhesiveness compared to control samples. Sterjovski et al. (2014) evaluated three leading Macedonian yogurt brands over 20 days discovering increased yeast counts dramatically during storage. Kalevska et al. (2019) evaluated the raw milk used for production at the "Bistra" Kicevo dairy and reported that the quality of yogurt is directly linked to the raw materials used in the Republic of North Macedonia. Dolevska et al. (2020) monitored yogurts from Mlekara AD Bitola over one month of refrigeration. They observed a significant increase in viscosity (from 693.5 to 1197.5 mPas) and titratable acidity as the product approached its expiry date. Conversely, the water holding capacity (WHC) decreased as storage progressed, indicating a weakening of the protein matrix.
Among these approaches, the use of botanical extracts derived from herbs and fruits has gained attention as an innovative way to improve both the nutritional quality and sensory characteristics of yogurt (Bloor, 2001). Herbal additives such as turmeric, sage, marjoram, and John's Wort contribute antioxidant activity while also affecting the rheological properties and physical stability of the yogurt protein matrix (Mishra & Goel, 2020; Savale & Sonavne, 2022; Le Ba et al., 2025). In addition, Sulejmani et al. (2020) reported that the addition of aromatic herbs to cheese increased antioxidant capacity and enhanced the overall aroma profile of the products.
The present study investigates the production of functional skim milk yogurt fortified with different herbal aqueous extracts in order to assess their effects on physicochemical characteristics, structural stability, and consumer acceptability. Optimizing the concentration of these botanical ingredients may enable the development of a value-added yogurt product with a creamy texture comparable to conventional yogurt, while also providing distinctive therapeutic and functional benefits.

Material and methods

*2.1. Materials : T*he raw material used for yogurt production was fresh skimmed cow's milk containing 8.8% total solids, 0.2% fat, and 3.2% protein, with an initial pH of 6.7. The fermentation was conducted using the YC-183 starter culture from Chr. Hansen. A variety of botanical herbs materials were utilized for fortification, including: Turmeric (*Curcuma longa*) rhizome powder, Sage (*Salvia officinalis*), Majoram (*Origanum majorana*) dried leaves, St. John's Wort (*Hypericum perforatum*), Hibiscus (*Hibiscus sabdariffa*), Stevia (*Stevia rebaudiana*), Silymarin (*Silybum marianum*), Parsley (*Petroselinum crispum*), and Dill (*Anethum graveolens*) (Table 1). Aqueous herbal extracts were prepared following the Bloor (2001) method. For each plant, 10g of material was added to 1000 ml of hot distilled water and processed in an electrical blender for 15 minutes. After standing at room temperature for one hour, the mixture underwent double filtration—first through cloth and then using Whatman No. 1 filter paper—before being stored at refrigeration temperatures. For Yogurt manufacturing process the manufacturing followed a structured work plan. The base milk was heated to 85°C for 5 minutes and then cooled to 42°C. The milk was divided into parts, including a control (no extract) and various fortified samples at levels of 1%, 2%, and 3% (w/w). Each part was inoculated with 2% activated YC-183 culture. The mixtures were filled into 100 ml plastic jars and incubated at 42°C until full coagulation was achieved, which typically took approximately 3 hours. Following fermentation, the samples were transferred to a refrigerator and stored at 5 ± 1°C until analysis.

Table 1. Methodology of Herbal Fortification Combinations

Name (Albanian/English)	Latin Name	Combination Levels (w/w)
Shafran indian (Indian Saffron)	*Curcuma longa*	1%, 3%
Zhallfia (Sage)	*Salvia officinalis*	1%, 3%
Kopër (Dill)	*Anethum graveolens*	1%, 3%
Kantarion (St. John's Wort)	*Hypericum perforatum*	1%, 3%
Majdanoz (Parsley)	*Petroselinum crispum*	1%, 3%
Kurkuma (Turmeric)	*Curcuma longa*	1%, 3%
Hibiskus (Hibiscus)	*Hibiscus sabdariffa*	1%, 3%
Stevia (Stevia)	*Stevia rebaudiana*	1%, 3%
Silimarin (Silymarin)	*Silybum marianum*	1%, 2%
Marjoram (Majorana)	*Origanum majorana*	1%, 3%

2.2. Physicochemical analysis: pH was measured using a digital WTW pH330 pH-meter after calibration with buffer solutions. Titratable acidity was determined via alkaline titration using 0.1 N NaOH and phenolphthalein indicator, with results expressed as a percentage of lactic acid. Total Solids were analyzed using method where samples were dried in an oven at 102°C for 5 hours until reaching a constant weight. Fat content was determined using the Gerber method, involving sulfuric acid and amyl alcohol followed by centrifugation at 1200 rpm for 5 minutes. Protein content was analyzed using the Kjeldahl method, where the nitrogen percentage was multiplied by a factor of 6.38. Standardized methods for assessing the quality (protein, fat, total solids, acidity, pH) of both the raw milk and the final yogurt were used (AOAC, 2007). Viscosity and Color were measured with a LST method (line spread test), and color was assessed using a Chroma Meter CR400 based on the system. Water holding capacity (WHC) was determined reliably using the centrifugation method described by Dolevska, et al. (2020).

2.3. Sensory Evaluation: Sensory quality was evaluated through a standardized survey capturing several parameters: aroma (likability), syneresis (whey separation), surface brightness, color (whiteness), cut clarity, and firmness (the ability to maintain shape after being scooped with a spoon). Testers also assessed characteristics such as sweetness, acidity, and oral resistance during swallowing. The results of the yogurt fortification experiment using various herbal extracts reveal significant variations in physicochemical properties (pH, acidity, and fat) compared to both control samples and findings from other scientific literature.

Results and discussion

Physical chemical characterization: The experimental data for the fortified yogurts, derived from an industrial skim milk base (8.8% total solids, 0.2% fat), are summarized below in the Table 2. The pH of the fortified samples primarily ranged from 3.46 to 3.77. St. John’s Wort (1%) exhibited the highest pH at 3.77, indicating lower acidity, while Dill (3%) was among the lowest at 3.46. A notable outlier was Turmeric (1%), which reached a pH of 4.54. Values for titratable acidity varied significantly between 0.28% and 0.73%. Indian Saffron (3%) showed the lowest acidity (0.28%), whereas Turmeric (1%) reached the highest level (0.73%).

Table 2. Physical-chemical composition of yogurt samples

Sample No.	Yogurt / Plant Extract	Conc.	pH	Titratable Acidity	Fat content
0	Control (no plant extract)	0%	3.23	0.55	1.00%
1	Indian Saffron	3%	3.50	0.28	0.80%
2	Sage	1%	3.48	0.56	1.30%
3	Dill	1%	3.52	0.46	0.20%
4	Indian Saffron	1%	3.63	0.55	1.30%
5	St. John's Wort	1%	3.77	0.32	1.30%
6	Parsley	3%	3.55	0.45	0.40%
7	Turmeric	3%	3.61	0.46	1.60%
8	Hibiscus	3%	3.47	0.44	0.40%
9	Hibiscus	1%	3.52	0.40	0.50%
10	Stevia	1%	3.76	0.48	0.20%
11	Dill	3%	3.46	0.62	0.80%
12	Stevia	3%	3.52	0.50	1.20%
13	Parsley	1%	3.53	0.48	1.30%
14	Sage	3%	3.55	0.59	1.00%
15	Silymarin	1%	3.56	0.43	0.30%
16	Turmeric	1%	4.54	0.73	1.40%
17	Silymarin	2%	3.53	0.45	1.30%
18	St. John's Wort	3%	3.60	0.42	1.50%

The samples in present investigation exhibited pH values between 3.46 and 3.77 and were more acidic than the results of Kalevska et al. (2019), who reported a pH of 4.45 for industrial yogurt in Macedonia after fermentation. This suggests that the plant extracts may have accelerated the kinetics of acidification, similar to Akgun's (2024) observations that specific treatments modify fermentation. For the fat content, because the base was skim milk, fat levels were generally low, ranging from 0.20% (Dill and Stevia) to 1.60% (Turmeric 3%). The St. John’s Wort 3%, had a fat content of 1.50%. So, fortification with herbal extracts serves to slightly increase the total solids, which according to dairy principles, enhances the viscosity and firmness of the gel network (Azis et all, 2025).

When comparing these results to the provided scientific literature, several key differences emerge. Tepe (2021) reported higher pH values for traditional and starter culture yogurts, ranging from 3.895 to 4.390. The herbal fortified samples in your experiment were generally more acidic (pH < 3.8), likely due to the specific metabolic interaction between the YC-183 culture and the botanical extracts. Sulejmani et al. (2014) emphasized that acidification caused by starter culture activity is a key step in producing high-quality dairy products. This principle was also observed during yogurt fermentation in the present study, where the decrease in pH toward the isoelectric point (pH 4.6) promoted casein aggregation and gel network formation. Furthermore, the same author reported that higher coagulation temperatures contribute to lower pH values and increased protein content in the final product.

The samples from the same investigation had higher titratable acidity (0.78%–0.89%) compared to most of present herbal samples (0.28%–0.62%), with the exception of Yogurt with Turmeric. Fat concentration from the same study resulted in yogurt with 3.0%–3.1% because it was utilized milk with 3.7% fat. So, samples in these investigation were significantly leaner (0.2%–1.6% fat) because they were produced from skim milk. Hashim et al. (2021) found that fortifying non-fat yogurt with whey protein isolate (WPI) increased the WHC to 50% and improved the microstructure. Similarly, your study found that St. John's Wort 3% and Hibiscus 1% achieved a superior structure with zero syneresis (whey separation), mimicking the stabilizing effects of WPI. Akgun's (2024) research on low-fat yogurt (2% fat) used high-pressure homogenization to increase firmness from 1.01 to 1.45 N. Herbal fortification achieved a similar "functional" goal; for instance, St. John's Wort 3% and Shafran 1% were rated as "Very firm" in organoleptic tests, effectively overcoming the structural weaknesses typically associated with low-fat/skim yogurts. Dolevska et al. (2020) observed that during storage in Macedonia, the viscosity of yogurt increases significantly after one month, but the WHC (water holding capacity) decreases. Serra et al. (2009) note that changes in protein chemistry directly affect water absorption similar to what was observed in St. John's wort 3% regarding firmness and syneresis. Sulejmani et al (2021) reported that higher acidity and protein content contribute to a firmer and more compact structure in white brined cheese. A similar trend was observed in the present yogurt study, where samples with higher acidity and fortification, such as the 1% turmeric sample (pH 4.54), exhibited greater firmness and a denser gel structure. The author further explained that interactions between milk proteins and added components, including vegetable fat or plant extracts, can enhance texture and firmness without negatively affecting sensory quality. Nguyen et al. (2015) support the findings related to syneresis (whey separation), explaining that the reduction in particle size improves yogurt stability and consistency. This phenomenon may explain why the best-performing samples in the present study showed no visible serum separation.

The use of St. John's Wort 3% resulted in the most balanced physicochemical and sensory profile (pH 3.60, 1.50% fat, zero syneresis), outperforming the non-fortified control (pH 3.23) and providing a more stable structure than the higher-fat traditional yogurts studied by Tepe (2021). In contrast, Silymarin 2% and Turmeric 1% were less successful due to unappealing aromas or higher acidity levels. Sterjovski et al. (2012) found that many brands of yogurt on the Macedonian market have problems with high yeast counts after 20 days of storage, so herbal fortification could serve as an additional microbiological barrier. Extracts such as Hibiscus are known in the literature for their antibacterial properties, which could help maintain the microbiological quality that previously were identified as a weak point in commercial products (Savale et al, 2022).

The sensory analysis of the fortified yogurt: Samples which utilized various herbal extracts identifies distinct impacts on aroma, structural stability, and consumer acceptance. St. John's Wort (Sample 18 - 3% and Sample 5 - 1%): These samples emerged as the overall winners. Sample 18 received the highest possible ratings for aroma ("Very liked"), showed zero syneresis (whey separation), and was characterized as "Very firm", maintaining its shape perfectly after being scooped. Hibiscus (Sample 9 - 1%): This sample was highly favored for its aroma ("Very liked") and excellent structural stability, exhibiting no syneresis. Indian saffron (Sample 4 - 1%): While the color was only "moderately white," it received a "Very liked" rating for aroma and was scored as "Very firm".

Silymarin (Sample 17 - 2%): Despite having a high fat content (1.30%), this sample performed poorly in sensory tests. It received an "Aspak" (Not at all) rating for aroma and showed " Sufficient) levels of syneresis, indicating a weak gel structure. Turmeric (Sample 16 - 1%): This sample was rated poorly for aroma and color, despite having a relatively high pH of 4.54. Parsley (Samples 6 and 13): These samples were generally rated as Sufficient or Moderate for aroma, though they maintained a firm consistency.

Minimizing syneresis is a critical quality indicator in yogurt production. The results show that St. John's Wort (3%) and Hibiscus (1%) were most effective at preventing whey separation (rating: "lowest"), suggesting these extracts help stabilize the protein network. This mirrors research by Hashim et al. (2021), where fortification improved water-holding capacity (WHC) to overcome the structural weaknesses of non-fat yogurt. Skim milk yogurts often suffer from a "weak body". However, the herbal fortification in this study significantly enhanced firmness. Samples like St. John's Wort 3% and Shafran 1% achieved a "Very firm" rating, performing similarly to full-fat control samples or low-fat yogurts treated with high-pressure homogenization, which improves firmness from 1.01 to 1.45 N. In traditional Balkan and Turkish dairy preferences, aroma and "cooling" taste are vital. Tepe (2021) noted that traditional homemade yogurts are often favored over commercial ones for their smell and taste. In this experiment, St. John's Wort and Hibiscus provided a superior aromatic profile that compensated for the lack of milk fat.

Tepe (2021) found no statistically significant difference in sensory scores for appearance and consistency over 15 days for traditional yogurts. In contrast, your fortified samples showed clear sensory differentiation based on the type and concentration of the herb used, with St. John's Wort significantly outperforming the non-fortified control (Sample 0) which often had lower aroma scores and some syneresis. The high ratings for firmness in St. John's Wort-fortified samples likely correlate with a denser protein network. As noted in the review by Le Ba et al. (2025), additives can reinforce the three-dimensional structure of the yogurt gel, fill the porous protein network and improve mouthfeel. Most samples, such as St. John's Wort (3%) at 0.42% and Hibiscus (1%) at 0.40%, maintained a balanced profile.

PCA clusters of fortified Yogurt samples: Principal component analysis (PCA) of the yogurt samples provides a multidimensional view of how different herbal fortifications influence the product's physicochemical stability and sensory appeal. By analyzing the variables provided in the sources—pH, titratable acidity, and fat content—alongside sensory responses, several key insights emerge regarding the quality of the 18 experimental samples. Most samples cluster between a pH of 3.46 and 3.77. In a typical PCA plot for yogurt, pH and titratable acidity usually show an inverse relationship; for instance, Sample 11 (Dill 3%) has a low pH (3.46) and high acidity (0.62), placing it at one extreme of the acidity axis.

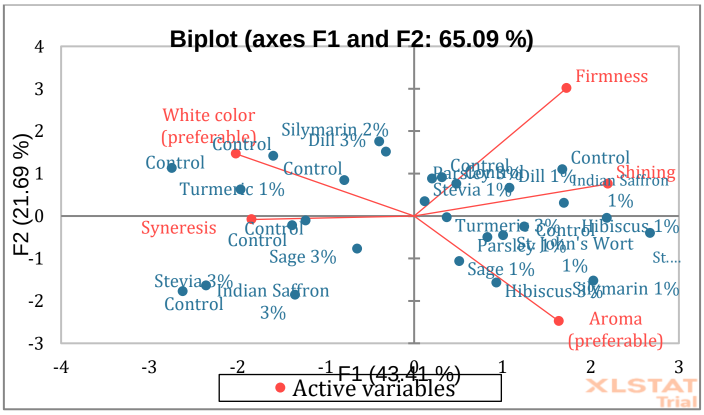

Figure 1. PCA clusters of the yogurt samples and sensory properties

For fat content, while the base is skim milk (0.2% fat), fortification levels adjusted the perceived or measured fat. Sample 7 (Turmeric 3%) and Sample 18 (St. John's Wort 3%) represent the high-fat end of the spectrum (1.60% and 1.50%, respectively), which significantly influences their positioning on the PCA plot. The PCA identifies a specific "success cluster" where physicochemical balance meets high consumer acceptance. Sample 18 (St. John's Wort 3%) and Sample 5 (St. John's Wort 1%) are the primary winners in this space. Sample 18, was characterized by pH 3.60, 0.42 acidity, and 1.50% fat. In sensory tests, it achieved maximum scores for aroma, firmness, and zero syneresis. Sample 5 with pH 3.77 and 1.30% fat is clustered near Sample 18, sharing its high structural stability and pleasant aroma. According to

Akgun (2024), PCA attributes like firmness and viscosity typically have high loadings on the first principal component (PC1), meaning these winners likely define the "positive" side of the quality axis in your study.
The PCA effectively separates samples that failed to meet quality standards. Sample 16 (Turmeric 1%) is a significant outlier with a pH of 4.54 and high acidity of 0.73. Its sensory scores were lowest for aroma and it showed poor color. Sample 17 (Silymarin 2%): Despite having a relatively high fat content (1.30%), it clusters away from the winners because it exhibited significant syneresis (whey separation) and an unappealing aroma. Control (Sample 0): With the lowest pH (3.23), the control sample represents a baseline of high acidity and low structural support from herbal extracts, often resulting in higher syneresis. Also, the PCA results align with broader dairy science principles found in present investigation. Akgun (2024) notes that high-pressure or specific fortifications can increase water-holding capacity (WHC) from 42% to 52%. PCA suggests that St. John's Wort and Hibiscus extract effectively mimic this structural reinforcement, as seen in the zero syneresis ratings for samples 18, 5, and 9. Hashim et al. (2021) demonstrate that increasing protein-like structures (via WPI or extracts) improves viscosity proportionally. The PCA of samples confirms that the 3% St. John's Wort level provides the densest protein network, leading to the highest scores for "clear cut" and "firmness".

Conclusion

Aroma was identified as one of the most influential factors affecting consumer acceptance, with the type of herbal extract playing a significant role in sensory perception. Yogurt samples fortified with St. John's Wort (1% and 3%), Indian saffron (1%), and hibiscus (1%) received higher aroma ratings, indicating high consumer preference, while the 3% St. John's Wort formulation demonstrated the most favorable aroma profile overall. In contrast, samples containing 1% turmeric and 2% silymarin were lowest rated for aroma, suggesting that certain herbal extracts and concentrations may negatively affect sensory acceptability among panelists. So, finaly technological fortification with 3% St. John's Wort proved to be the most effective approach for producing a non-fat functional yogurt that meets consumer expectations for high firmness, absence of syneresis, and a highly pleasant aroma. Furthermore, herbal fortification may serve as an additional microbiological barrier, since extracts such as hibiscus are recognized in the literature for their antibacterial properties, which may help preserve quality.

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